FROM FLATLAND TO HIMALAYAS: THE HISTORICAL OROGENY OF U.S. NAVY MODEL OROGRAPHY

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1. INTRODUCTION

Numerical weather prediction models face the challenge of selecting appropriate surfaces to represent their lower boundary. From smooth topography to silhouette orography, the choice of surface terrain has been constrained by factors such as grid resolution and the analytical methods in use. Practical considerations had required employing various digital elevation models that are subsampled and filtered to fit the resolution of the forecast model. There was recognition early on that the height and characteristics of terrain chosen affect model skill (Kesel and Winninghoff 1972) and so as numerical models improved, their orography became more refined. This paper outlines the development of terrain fields used in U.S. Navy environmental prediction models at Fleet Numerical Meteorology and Oceanography Center from 1970 - 2004.

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2. GLOBAL FORECAST MODEL HISTORY OF OROGRAPHY

The five-layer primitive equation model of the northern hemisphere began running operationally at Fleet Numerical Weather Central (FNWC) in 1970. Kesel and Winninghoff (1972) describe the model domain of 59 x 59 grid points with plans for the underlying terrain to use values taken from a 10-minute terrain set completed by Leo Clarke of FNWC -- the origin of the U.S. Navy 10-minute global terrain field. Mihok and Kaitala (1976) explain the later evolution of the full global primitive equation model at FNWC on a staggered spherical coordinate system, but did not elaborate on the model terrain.

Starting in 1976, the Naval Environmental Prediction Research Facility (NEPRF) began developing the Navy Operational Global Atmospheric Prediction System (NOGAPS) using components from the UCLA general circulation model to build the first version (Rosmond 1981). References to model terrain during this period were sparse. The dynamics had been described by Arakawa and Lamb (1977) and there is mention of the model orography which UCLA used (Mechoso et al. 1979) but not of the subsequent orography chosen for NOGAPS. A comparison of the Northern Hemisphere primitive equation model to the

UCLA model (Payne 1980) does not discuss the subject of orography either.

In January 1988, NOGAPS 3.0 replaced the prior version with a new global spectral model. Its horizontal resolution of T47 utilized orography constructed from the Navy 10-minute terrain field. Hogan and Rosmond (1991) explain how the terrain was enhanced through a silhouette method followed by a Lanczos (1956) filter to minimize negative terrain heights common to spectral truncation.

Higher resolution terrain fields were implemented in September 2000, using the former NIMA Digital Terrain Elevation Database (DTED) Level 1 data, again enhanced by the silhouette method. Then in November 2003, new orography for NOGAPS was implemented using the USGS Global Land One-kilometer Base Elevation (GLOBE) database. The use of mean terrain heights instead of silhouette resulted in lower heights over high plateaus by as much as 600 meters (see Figure 1). Again a Lanczos filter was applied. With a resolution of T239 (approximately 0.5 degree or 55 km) this is the current NOGAPS orography in use today (see Figure 2).

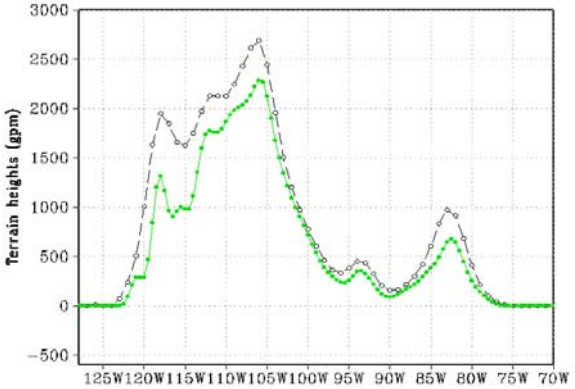

FIG. 1. Profile of North America along latitude 36 N, depicting silhouette orography from NIMA DTED Level 1 terrain data (dashed black) versus mean orography using USGS GLOBE data (solid green).

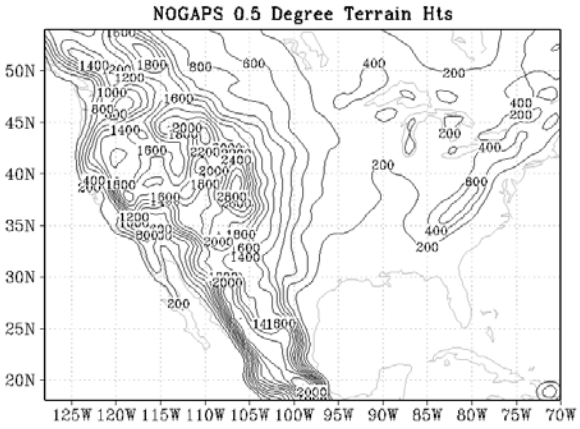

FIG. 2. Example of the North American terrain heights currently used in NOGAPS (contour interval is 200 meters).

3. HISTORY OF REGIONAL FORECAST MODEL OROGRAPHY

The development of regional forecast models at NEPRF led to the implementation of the Navy Operational Regional Atmospheric Prediction System (NORAPS) by 1981. The terrain field in NORAPS was bilinearly interpolated from the Navy 10-minute terrain height database, with a 9-point smoothing filter applied (Hodur 1982). Subsequent improvements to NORAPS over a five-year period included enhancing the mean terrain by adding the standard deviation of terrain heights computed within centered 2^o X 2^o areas from the Navy 10-minute field (Hodur 1987).

By 1995 the Naval Research Laboratory (NRL) successfully implemented a nonhydrostatic regional model, the Navy Coupled Ocean / Atmosphere Mesoscale Prediction System (COAMPS), using terrain heights bilinearly interpolated from DTED Level 1 data. Within nonhydrostatic models the prediction of externally forced modes depends upon flow interaction with orography, making the correct specification of terrain critically important (Hodur 1997).

As the resolution of regional models continues to increase, skillful prediction will depend even more upon an accurate definition of the lower boundary.

4. SUMMARY

The development of terrain fields for numerical weather prediction has been an integral part of model improvements over the years. Models at Fleet Numerical Meteorology and Oceanography Center first utilized the U.S. Navy 10-minute global terrain data, and more recently digital terrain databases from other mapping agencies to take advantage of increasingly high resolution orography. From coarse model domains which span 59 x 59 grid points to today's high resolution COAMPS, the selection of model terrain has been shown to influence forecast skill and will continue to be a factor in the future.

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